THE BEGINNING OF AGRICULTURE

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The following pages record a few observations and generalizations made incidentally in the course of an expedition through the little-known region in Arizona and Sonora (Mexico) called by Spanish-Americans "Papagueria," or land of the Papago Indians. The primary purpose of the expedition, which was made under the auspices of the Bureau of American Ethnology in conformity with plans of the Secretary of the Smithsonian Institution, was the making of a collection representing the arts and industries of the Papago Indians. In part the observations recorded herein pertain to subjects concerning which no expert knowledge is claimed; in so far as they relate to plants and animals they are merely such as any intelligent traveler through a region of pronounced peculiarities might be expected to make;* but the observed relations of plants, animals, and men, among each other and to their common environment, were studied with care and generalized with some fullness. Throughout the expedition the question as to the influence of a peculiar environment on mankind, individually and socially, was constantly borne in mind; and it was this question that directed the observations and generalizations. The principal conclusion is in accord with the opinion of Powell and some other students concerning primitive agriculture, but the generalizations and inferences are independent, and the line of induction is new.

CHARACTERISTICS OF THE REGION

Papagueria is an indefinite territorial unit varying with the migrations of a nomadic people, and thus with human whim and seasonal succession. In a general way, it lies south of Gila river in southwestern Arizona, west of the great Sierra Madre of western Mexico, and northeast of the Gulf of California. Its northern

* It is a pleasure to acknowledge obligations to Mr Wm. Dinwiddie, the photographer of the expedition, for excellent photographs of the plant forms referred to, and to Mr F. V. Coville and Dr J. N. Rose for identifying several species therefrom.

and eastern limits were originally fixed by interaction against the Apache and other predatory peoples, or rather by an assemblage of geographic conditions involving the presence of water in sufficient quantity to maintain hunter and robber tribes; the western boundary is the limit of habitability to *the* desert-loving tribe, par excellence, of North America; while on the south the land of the Papago merges into that of the Opata, Nevome, and Yaki or abuts sharply against the domain of the bloody Seri. From the Gila on the north to the rancherias beyond Rio Sonora on the south, Papagueria measures some 400 miles; on the international boundary it is nearly 200 miles broad, narrowing southward; the area in round numbers may be 50,000 square miles.

From the foothills of a massive mountain range the land of the Papago slopes southwestward as an undulating plain with many minor mountain ranges rising sharply from its surface along lines generally parallel with the great Sierra. Streams gather in the Sierra and in the higher embossed ranges, and the larger of them flow in the intermontane valleys northward and southward from a subcontinental divide coinciding closely with the international boundary; but in their middle or lower courses these stronger streams trend southwestward across the valleys and athwart the axes of the minor ranges toward the Gulf of California. The great streams heading in the Sierra Madre—"Mountain Mother [of waters]"—carry vast floods in their middle courses during the rainy seasons, while at ordinary stages they are but slender brooks; and between the Gila-Colorado and the powerful Yaqui (the Indus of Mexico, whose far-reaching affluents with their hundreds of tributaries drain most of the high Sierra) even the freshet waters are absorbed by the dry air and the thirsty soil, and none of the rivers reach down to the sea. The smaller streams are more erratic in direction, but the smaller and the larger are alike in general character; all head in the mountains and, gathering volume from tributaries, flow along or athwart the intermontane valleys for longer or shorter distances, and then dwindle or disappear as the waters evaporate or sink; for a few hours or days after the storms of the rainy seasons all are rushing torrents, and then for days or months they are but slender brooks or broad wastes of sun-parched sands. All the waterways are deep and rugged gorges or gulches—the "barrancas" of the Mexican vernacular—toward the sources,

broad steep-banked and sand-lined arroyos in the upper valleys, and expanded deltaform silt sheets in the lower valleys; and in all permanent streams the midlength arroyo of the upper valley is cut out and maintained by the brimming floods of the rainy seasons despite the feeble sedimentation of the narrow streamlet wandering over the channel bottom during the dry season.

Papagueria, with its western borderland skirting the Gulf of California, is perhaps the most arid region of equal extent on the western hemisphere. The annual precipitation over the portion lying in Arizona, according to the latest charts of the United States Weather Bureau, ranges from about three to something over ten inches, the maximum occurring only in the Sierra Madre on the east; the average west of the Sierra is probably less, and toward the gulf much less, than five inches. On the Sonoran side of the subcontinental divide the rainfall is undoubtedly a little greater, though trustworthy figures are lacking. Within the region the districts of January-February and July-August rains overlap, and there are thus two rainy seasons during each year. To this circumstance many of the characteristics of Papagueria may be ascribed. In the first place it is probable that if the rainfall were concentrated in a single season, the storm freshets would be greater and a part of the scant water supply would escape into the gulf, rendering the region more desert than it is; in the second place the semi-annual watering and checking of evaporation vivifies the flora and doubtless enables many plants that could not survive a ten-month drouth to maintain themselves—certainly the semi-annual rain is a condition to which the vegetal and animal life is adjusted, as shown by the two seasons of leafing and flowering of different forms.*

The higher ranges near the Sierra are thinly clothed with pines, oaks, and their associates; the larger foothills as well as the lesser ranges and the higher portions of the intermontane plains are still more scantily mantled with cactus, yucca, agave, several mimosas, acacia, paloverde, and meager thickets of chaparral; many of the great alluvial aprons which characterize this region of subaerial planation are given over to cacti and related plants of many genera and species, with scattered stems of grasses and occasional

* Johannes Walther has shown that the flora of the American deserts is richer than that found in the deserts of the Eastern Hemisphere. Nat. Geog. Mag., vol. iv, 1893, p. 166.

tufts of greasewood and rabbit-brush; the intermontane valleys are sparsely dotted with mesquite and related mimosas, and an occasional paloverde and the creosote bush in season, intervening with vast treeless glades supporting nothing but widely scattered blades of silver grass, or with stretches of greasewood and other prickly shrubs; while the barrancas and the midlength arroyos of permanent streams are flanked by cottonwood, willow, giant mesquites 40 to 75 feet high, sycamore, ash, and other trees, with a rank undergrowth of shrubs, grasses, canes, and vines, all growing in tropical luxuriance. Viewed collectively, the flora is fairly rich in species, wretchedly poor in individuals; by reason of the vegetal extravagancies of cactus, agave, yucca, and aberrant tree-type, the flora is multiform when individuals are viewed, but by reason of a prevailing tendency in the differentiation of distinct types it becomes monotonously uniform when viewed collectively. Leaves are lacking or small and close-folded; stems and trunks are prevailingly gray-green and waxy, and thorns abound on all the floral forms; yet, though many mountains are almost barren and many valleys are nearly bare, vegetation is never totally absent save from a few shifting sand wastes and the coastward malpais—the "bad land" of Mexico.

The animal life is largely nocturnal and crepuscular, and the day traveler sees little of the fauna. The most conspicuous animate creature, by reason of its works and the number of individuals to be seen, is the farmer ant, whose well-kept fields and clean threshing-floors dot the great alluvial aprons and some of the higher intermontane valleys by tens of thousands—indeed, a quarter, if not a third, of Sonoran Papagueria has been reclaimed by these thrifty husbandmen for their own uses, so that a full half of the grass to be seen in a day's journey is that which the farmer ants have, apparently, cultivated and fertilized. In the lower valleys, along with the scattered mesquites, the southwestern ground squirrel abounds; in the annually flooded deltas, as well as along the mountain slopes, the California quail and a variety of smaller birds, with a few of larger size, are found; hawks and, in Sonora, eagles are often seen, while the jackrabbit and coyote are never far away; lizards, bright-colored and somber, are hourly in view; the horned toad is seen now and then; spiders, including the tarantula, are plentiful save in the driest valleys; scorpions are common, and in some localities rattlesnakes abound.

Though the diurnal fauna is rather meager, it is probable that the fauna as a whole is, like the flora, fairly rich in species though poor (yet hardly so poor relatively as the flora) in individuals.

CHARACTERISTICS OF THE VEGETAL LIFE

Perhaps the most conspicuous feature of the flora, except on the higher mountains, is the dearth of foliage. The distinctive desert types—cactus, yucca, agave—are leafless. The mesquite, the prevailing arboreal form, is indeed leaf-bearing, but away from the naturally or artificially irrigated valleys the leaves, always small, are so reduced in number and size as scarcely to conceal the twigs and branches, and during the long dry seasons the oppositely arranged pinnate laminæ are so closely folded as to display little verdant surface; the greasewood (*Atriplex* of several species) and rabbit-brush are also small-leaved and their foliage, like that of the mesquite, folds up or falls off during the four-month drouths. Most of the paloverdes are leafless throughout the greater part of the year, some of them are said to be always; and whole acres of chaparral are almost entirely leafless during the drier months, displaying only a greenish gray or bluish brown wilderness of trunks, branches, thorns, and naked petioles. Even in the valleys where the trees drink from the sands below rather than from the air above, and where trunks, stems, and fruits are luxuriant, the dry-season foliage is scanty and the leaves are folded or rolled in such manner as to present a minimum surface to the air and to view—the pinnate leaves fold along the midrib, the palmate leaves of the sycamore roll themselves into slender cylinders, while other trees shed a part of their leafage soon after the end of each rainy season, to send forth a fresh foliage with the beginning of the next. Away from the watercourses the smaller shrubs are leafless brambles; and even the grasses are strong-stemmed with short and narrow blades. The humid lands of the lower latitudes are clothed with the foliage of trees, grasses, and other annual and perennial plants during most of the year; but in Papagueria, as in other semi-desert regions in some measure, this mantle fails and the land is naked or at best thinly veiled by earth-colored stems and branches, so that the plains and hillsides are more barren in appearance than in reality and often belie their own fertility.

Nearly as conspicuous as the absence of foliage is the presence of aberrant types, chiefly of robust, pulpy forms, peculiar to the desert. The great saguaro (*Cereus giganteus*), rising 20 to 60 feet in a single stem 1 to 3 feet in diameter or in a massive candelabrum, bare in the distance as a carved monolith, is the dominant form; and its huge waterlogged stems, ghostly grayish by night and ghastly greenish by day, are unlike the typical plant forms of the earth and impress the traveler as incongruous with nature. In Sonora the congeneric pitahaya abounds; with its great curved branches, each a tree-trunk in size and a mushroom in texture, it is nearly as extravagant in comparison with typical plant forms as the saguaro. Over the lower plains the closely related and equally monstrous cina (*Cereus schotti*) takes the place of saguaro and pitahaya, and dominates the shrubbery. The okatillo (*Fouquiera splendens*) with its bare, wide-branching stems approaches somewhat more nearly, and the tree-okatillo (*Fouquiera spinosa?*) still more closely, normal arboreal forms; but the nopal and nopalito (*Opuntia*, different species of the flat-stemmed type) are no less aberrant, though less conspicuous than the saguaro. The cholla (*Opuntia* with cylindrical and prismatic stems) and other arborescent cacti are fairly congruous with trees and shrubs in general habit, though not in texture, and thus contribute measurably to the strangeness of the landscape. The agaves and yuccas are only less striking than the cacti; and the pale green, bare-branched paloverde (*Parkinsonia torreyana*), with slender needles or minute pinnate leaves in lieu of normal foliage, is hardly less aberrant. This assemblage of incongruous plant forms gives character to the desert landscape.

Another conspicuous feature of the flora of Papagueria, like other desert regions, is the abundance of thorns, with which nearly all the plants are beset. The saguaro and pitahaya and their kind are armed with lines of chevaux-de-frise extending from base to summit; the nopal and the cholla are set with wide-branching bunches of barbed needles; each branch of the okatillo bristles with a thousand spines, and the water-bearing visnaga (*Echinocactus wislizeni lecontei*) is crowned and clothed with an impenetrable armor of natural bodkins and fishhooks. The yuccas and agaves abound in serrated and plain knife edges, and in many species the needle-tipped and spike-fringed fronds turn outward and downward in serried armature. The chaparral is

a wilderness of thorns; the dwarfish oak trees on the mountain sides are beset with needle-pointed knobs; the mesquite and smaller mimosas on the more arid plains bristle with thorns, and during the dry season the shriveled and case-hardened petioles are transformed into cruel spikes; the greasewood and other shrubs are crowded with irritating spines and bristles, and even the mild-aired paloverde is armed with pointed and sharp-edged processes. Certain ephemeral plants that spring up about the burrows in the shadow of the mesquite trees have holly-like thorns at the serrate leaf-tips, and the grass blades are knife-edged and needle-tipped, while the seeds are enclosed in spiked hulls or fringed with spiny awns. In all the land of the Papago there are few indigenous plants that are not armed with thorns or spikes or spines, or all combined.

The thorniness of the desert plants is associated with a peculiar modification of the surface of stems, leaves, and fruits, often in the direction of cutinization, sometimes in the direction of hairy coverings.* From root to terminal twig the paloverdes are glazed with a resinous epidermal tissue; the pulpy stems of the saguaro and its congeners are enclosed in a thin but strong waxen skin, grading into the natural lacquer coating the spines; the mature leaves of the arborescent flora on the mountain sides and along the waterways alike are thickened and harsh rather than velvety of surface, and many appear to be coated with natural varnish; a few trunks are rough-barked, but usually the branches and twigs are smooth and case-hardened. The seeds of the saguaro imbedded in the pulp of the fruit are hard and shining of surface; the mesquite beans are firmly implanted in woody pods, yet are smooth and hard, and the smaller mimosa over the Sonoran slopes bears beans in a thin-walled pod that are as hard and glossy as lacquered lignum-vitæ; and the fruits and seeds of annuals are so hard as to form a favorite material for beads among the Papago women and children. Many of the shrubs bristle with a stiff pilage from root to petiole, and sometimes the leaves are hairy or coarsely furred, particularly as the moister season wanes; and many of the bristles are barbed and brittle, and hardly less forbidding than the thorns and spines.

Another noteworthy characteristic of the plants of Papagueria is the green color of the stems and trunks. In humid lands the

* The hairiness of the desert plants has been noted by Coville in Death valley.

foliage is green, the trunks and stems generally gray or brown or black, the grasses green throughout, while in the arid regions, where the foliage is largely lost, the verdure pervades the permanent body of the plant; the nopal may become purplish or yellowish and the okatillo gray or brown, the trunk of the cholla may turn dark brown, but in all there is an element, and generally a predominant element, of green, and when the setting sun reddens the chance cloud banks even of the dry season the complementary green of the cacti-clothed landscape becomes almost brilliant. The yuccas and agaves are green, greenish gray, or greenish yellow, yet never without the element of green; the paloverdes are a soft and sickly green from root to topmost twig; all of the minor and many of the main branches of the mesquite and chaparral are tinged with green; the creosote bush (*Larrea tridentata* or *mexicana*) is a dark rich green, especially during the winter months; even the silver grass is seen in the reddened rays of the setting sun to show a greenish shade. The predominant tone of the desert landscape is gray, the color of bare earth and rock; but there is a strong undertint of green coming from the tenuous veil of stark and thorny albeit leafless vegetation.

In much of Papagueria these features are partially masked and the landscape transformed during the rainy season. Even a casual dry-season storm produces a decided change: The pinnate leaves of mesquite and paloverde and smaller shrubs open and fresh leaflets appear, and the foliage-bearing plants partially eclipse the cacti; in the arroyos the willow and ash leaves expand to their widest, the sycamore leaves unroll, and the yellowish green foliage of the cottonwood brightens; with the expansion of the old leafage and the burgeoning of the new the prevailing thorns are concealed; the desert varnish softens and stretches with the growth of trunks and branches; the silver-gray grasses assume a greener tinge, and in the general verdure the sickly green of the cacti and agaves pales by contrast.

The seasonal changes no less than the dry-season characteristics of the desert flora suggest a meaning for the assemblage of distinctive features. The seasonal changes indicate that certain features, like the dearth of foliage, are partly, perhaps largely, individual or on ogenic; while the persistence of certain features, such as the development of aberrant forms, the permanence of thorns, and body verdure, appear to be essentially phylogenic.

The chief function of the leaf is transpiration; but in the heated air and long drouth of the arid land a constantly transpiring plant soon withers and dies. So it would appear that in some way, through the law of natural selection, plants of luxuriant foliage have been eliminated (save along the lines of abundant groundwater), leaving plants of scanty foliage to dominate the soil. Moreover, under natural selection, as it would appear from comparison either of given species or of the floral assemblage with those of humid regions, an individual plasticity has been developed whereby the functioning of the foliage is rendered periodic in an exceptional degree; and those individuals persist and leave most progeny that are best able to adjust the rate of transpiration to the varying conditions of season. The adaptive devices developed in this hard environment are many and suggestive. Compound pinnate leaves fold easily, and so plants bearing this type of foliage abound, and some, like that of the mesquite, have become so delicately adjusted to external conditions as to fold under shock even in the humid season—indeed sensitive plants abound throughout the deserts. The rolling up of the palmate leaves might almost be termed an ingenious device and interpreted as an index of high intelligence in the tree; and the prompt burgeoning of new leaves as the air grows humid and the rain comes down is an almost pathetic expression of gratefulness, and indicates a wonderful delicacy of adjustment between organism and environment. The leaf-bearing plants of Papagueria are conspicuously characterized by certain collective habits rather than by classific features; it is by means of these habits that they are enabled to survive the nearly continuous drouths; and thus while the habit is individual in expression, it is undoubtedly hereditary in the perfection of its development. The inference from the foliage-bearing trees is sustained by the facts of the development of other plant forms, like the cacti and the paloverdes, in which leaves are lacking. The cacti represent an aberrant type, but the paloverdes are trees in all characters save the color and texture of the bark and the dearth or absence of foliage; they prevail only in arid regions, and in the drier localities displace even the deep-rooted mesquite and the abstemious greasewood; and they are undoubtedly the product of a long-continued process of adaptation through natural selection to an arid environment.

The predominance of thorns may in part be correlated mechanically with the elimination of foliage, for as the lamina withers the petiole or axillary processes sometimes shrink and case-harden and become potential thorns; but the vast multiplication of real thorns cannot be so explained. An explanation appears when the relations of the plants and herbivorous animals are studied. The thornier plants are better protected from the animals, and thereby their chances of survival and procreation are enhanced. Moreover in the arid region, unlike the humid land, the struggle among species is not territorial or numeric but individual;* it boots nothing to the plant to yield ten thousand seeds where only ten young plants can be supported; and it is of no avail to a species in the unconscious effort of vegetal vitality to cover its vicinity with progeny so abundantly as to exclude other species, since the parched soil will support but a few plants, and parents and progeny alike would famish. In the humid land the species is perpetuated through multiplication of individuals, and within limits through territorial dominion; but in the arid land the relations are changed, and perpetuation of the species is secured chiefly or solely through prolonging the life of the individual. Thus the thorny armature is doubly beneficial; for it first prolongs the life of the individual, which is preëminently essential to the perpetuity of the species where only a few individuals can exist, and then increases the chances of long-lived progeny in sufficient yet not redundant numbers. These relations suggest that the desert plants should be found exceptionally long of life and exceptionally scant of seeds; and while further observation on these points is needed for demonstration, and while some other relations enter, there is reason to opine that long life of individuals and either limited numbers or small size of seeds are characteristic of the desert flora—*e. g.*, the typical saguaro bears minute seeds, though in considerable numbers, and is exceedingly slow of growth. The many adaptive devices of plant effort for wide distribution of seeds and phytons (for the cholla and perhaps other cacti seem to have re-

*Coville, speaking of the flora of Death valley (Contributions from the U. S. National Herbarium, vol. iv, p. 43), says: "It is evident * * * that desert shrubs essentially present in their environment the anomaly of a struggle for existence, not against other plants, but against nonorganic physical forces alone." This admirable report was not seen until after the expedition to Papagueria, nor indeed until after these paragraphs were written.

verted to the mode of reproduction by vegetative propagation *) must be passed over; it suffices to note that the development of a protective armature of thorns in arid lands seems to be natural and necessary and the outcome of phylogenic modification. It is significant that in the case of thorns, as in the case of scant foliage, a characteristic habit of unrelated plants rises above specific affiliations—taxonomically the flora is widely diverse, but in this as in several other characters it is singu'arly uniform in habit, so that the specific differentiation of the ages is partly masked by a conspicuous unification in a certain direction.

The lacquered and pilose surfaces of desert plants affect transpiration. With the cutinization of leaves the stomata are contracted or covered, with the exudation of resinous or waxy substances the twigs and trunks become coated with an impervious varnish, and with the natural lacquering of the seeds they are preserved unto the ensuing moister season when the lacquer softens and the germ quickens; the barbed bristles of leaves and stems protect them from at least the smaller herbivores, the harsh or soft pilage catches and holds the moisture from the rare rains and dews, and the pubescence measurably protects the plant against changes in temperature.† Thus it is evident that the cuticular modification of the desert plants is beneficial individually and hence phylogenically; and the noteworthy development of these modifications, like the other characteristics of the flora, may be explained as adaptations through survival of the fittest.

The cactus is essentially a reservoir of water pumped from beneath and confined by a thin yet impervious shell, protected by an armature of thorns; and though of different form, the agave and yucca are essentially similar in plan. So the aberrant plant types characteristic of the desert are most conspicuously, if not preëminently, adaptive devices for the storage and presumptively for the most effective use of water; in them the energy of the plant is mainly expended not in the multiplication and diffusion of individuals, nor in energetic growth of individuals, nor in the development of permanent structures (for the cacti are notable for their paucity of woody or other permanent tissue), but in storing a single substance against the time of scarcity that the

* Toumey has recently described the mode of reproduction of *Opuntia* in southwestern Arizona by the distribution of joints or fragments.

† The last-named function of the plant hairs is specifically recognized by Coville.

individual may maintain a lowly and feeble vitality for a long period. The roots of the pulpy desert plants are long and often large; yet when these plants are compared with the vegetal organisms of humid lands, it seems manifest that the function of the water collected by the roots and stored in the stems is peculiar—the substance appears to perform its duty not so much by flowing through, as by remaining in, the tissues. Accordingly the desert plant appears to be an exceptionally effective mechanism for utilizing the power of water, a high-power chemical engine rather than a low-power hydromotor; and the predominance of these forms may be ascribed to the selection and development of this peculiar quality through survival under adverse conditions. The phylogeny of the pulpy desert plants is obscure; but it is probable that the genera and species were developed with relative rapidity during the later geologic periods to fit the peculiar assemblage of conditions found in arid lands. Yet although geologically modern, they are in many respects allied to primitive plant types, and are in many ways antithetic to the higher types differentiated during the ages to fit the conditions commonly prevailing over the lands of the earth. Thus the forms are aberrant, incongruous with prevailing vegetation, though accordant with a distinctive set of conditions; and in the development of this accordance they have assumed the habits of leaflessness and thorniness impressed on unrelated forms by the same rigorous conditions; so that the adaptive similarities have in some respects eclipsed real homologies.

The paloverdes are enclosed in an impervious glazed skin or bark, somewhat resembling the dermal covering of the cactus and agave; their conspicuous feature, which they share with the pulpy desert plants, is the green color due to abundant and widely diffused chlorophyll. Similar coloration, though generally in less degree, prevails in the trees and shrubs of Papagueria, where twigs and smaller branches, if not main stems, are commonly greenish, sometimes clearly green as in the paloverde. Now, according to Lommel and others, and as taught by Vines,* the function of chlorophyll is to absorb certain rays of light, and thus to enable the protoplasm with which it is connected to avail itself of the radiant energy of the sun's rays for the construction of organic

* Lectures on "The Physiology of Plants," Cambridge, 1886, Lectures IX, XIII, XVII, etc.
† Ibid., p. 157.

substance from carbon dioxide and water.† Considering chlorophyll with its associated substances as an adaptive mechanism for utilizing the energy of light for the behoof of the plant in which it is produced, then it is especially beneficial to the meager flora of the desert; for not only are the individual plants so widely scattered that the solar rays reach all parts of the organism above ground level, but the insolation is much stronger than in humid lands, and is rarely checked by clouds. It seems probable, too, that the exceptionally effective utilization of water in the pulpy plants is directly connected with the action of the chlorophyll; but whether this is the case or not, the abundant development of chlorophyll in the stems and trunks of leafless or scant-leaved plants is unquestionably adaptive through the survival of the chlorophyll-bearers.

The great lesson of vegetal life in Papagueria is found in the delicate adjustment of the varied flora to the dominant condition of aridity. Some species are adjusted to the condition largely by modified habit of foliation; other species, like the paloverdes, represent profound modification of the arboreal type; while the dominant forms, cactus, agave, and yucca, represent still more profound modification of subarboreal, if not primordial vegetal types; and all of the plants, howsoever divergent phylogenically, are notably convergent in a certain group of characters, including leaflessness, waxiness, hairiness, thorniness, and greenness. By some naturalists the divergent characters of organisms are classed as natural or biotic, the convergent or composite characteristics as artificial or demotic; but under this classification the common peculiarity of the unrelated desert plants would become vegetal artificiality. This distinction need not be pursued; it suffices to note that the desert flora reveals in strong light the exceeding adjustability of even the more fixed organic types to environment, an adjustability so delicate that the affinity thereof masks and modifies consanguinity.

Great interest attaches to the Papago Indians as the inhabitants of a desert; yet the extent of the interest can be appreciated only when the exceeding rigor of their environment, as manifested by the flora of the district, is understood. Even if the Papago were not interrelated with the flora, as will appear later,

it would be desirable to consider their relations to an environment which transforms the stabler organisms of the earth.

CHARACTERISTICS OF THE ANIMAL LIFE

A noteworthy feature of the animal life of Papagueria is the protective coloring of many of the birds, animals, and reptiles. The quail and dove are slaty-gray and not easily discriminated from the gray or ashen earth, rocks, and plants of their haunts; the coyote approaches the color of the ground with its scant vegetal coloring, and is said to change color with the seasons, becoming darker with the wet, lighter with the dry; the lizards are in part bright-colored but in part gray, brown, or leaden, and some are chameleons, changing color with their surroundings; many insects, too, display protective coloring, and some, like the mantis, have acquired twig-like or leaf-like forms. These characteristics of imitative protection are prominent, yet perhaps not more constant than in other regions.

Another feature of the animal life is the fleetness and staying power of a considerable number of animals, including the deer, antelope, jackrabbit, coyote, and certain smaller mammals, as well as the bright-colored lizards and some of the hawks. Collectively the fleetness of the fauna may be adventive rather than characteristic, yet it is of interest in connection with another feature with which it would appear to be reciprocally related—*i. e.*, the venomous character of various sluggish animals. The latter feature is one which cannot easily be evaluated by reason of the frequently absurd popular beliefs on the one hand, and the antithetic tendency to exclude all evidence of venom on the other hand. It is certain, however, that the rattlesnake, which abounds in some localities and is probably the most numerous ophidian, is both sluggish and venomous; the dull and slow-moving Gila monster (*Heloderma suspectum*) is almost certainly venomous, at least under certain conditions; the indolent but pugnacious tarantula is undoubtedly poisonous; the apathetic scorpion and the clumsy centipede are more or less poisonous; the bite of the greatly feared though lazy large-head ant of Sonora and other Mexican provinces produces festering sores, whether with venom or otherwise; there are a variety of wasps, including one of great size and slow movement, whose stings are

poisonous; in southern Sonora the local katydid is more feared than rattlesnake or tarantula, its sting being supposed invariably fatal; and there is a large body of evidence indicating that the sluggish skunk under certain conditions communicates a poison akin to that of rabies. Thus a notably large number of animals are known or supposed to be venomous; even excluding all concerning which there is reasonable doubt, the ratio of venomous to non-venomous species would seem to be large. Granting the presence of venom, it may easily be explained as the prevalence of thorns among the flora may be explained: In a region capable of supporting only a relatively small number of organisms per unit of area, the perpetuity of species is best secured by the protection of individuals. Now certain lizards, insects, and birds are protected by mimetic coloring or form, the *Phrynosoma*, like the plants, is guarded by a thorny armature, and the chameleons are shielded by a physiologic mechanism for color-change; but it would seem that venom forms at the same time a more effective and a more economical means of protection, perfected by phylogenic modification through survival.

At first blush the fauna of Papagueria displays less of modification than the flora in the direction of fitness to a rigorous environment; and this relative immunity may be ascribed to the power of locomotion, which permits animals to emigrate from the most arid sections during the driest seasons, so that the mechanism of locomotion partly replaces the static mechanism of resistance developed in the stationary plant. On closer examination it is found, however, that the immunity of the animals from desert transformation is apparent rather than real; the animals, no less than the plants, are delicately adjusted to their environment; but the modification is superorganic or social rather than organic, as in the case of plants. This faunal modification is of special interest to the student of desert tribes, in that it is a connecting link between man and lower organisms.

THE COÖPERATIVE CHARACTERISTICS OF LIFE

Although the animals and plants of Papagueria display pronounced individuality, and although some of their most prominent features are adaptive devices for securing independence, a striking peculiarity of the region is the coöperation among living

things. Along the lines of groundwater the species are measurably or wholly antagonistic to their neighbors of distinct species; but over the arid uplands and in the broad waterless valleys all plants coöperate, not only with plants of distinct species but with animals, for the maintenance of common existence. Sometimes the coöperation involves little modification and no loss of individuality on the part of the agents; this type may be called *communal:* in other cases the coöperation is so intimate that animals and plants are not only mutually helpful but so closely interdependent that neither could exist without the aid of the other; this type may be called *commensal.*

Communality.—A mesquite springs up on the plain; within two or three years the birds resting in its branches drop the seeds of cacti, some of which, like vines, are unable to stand alone; and the cactus and the mesquite combine their armature of thorns for mutual protection. Then wind-blown grass seeds lodge about the roots, and grasses grow and seed beneath the sheltering branches; and next small mammals seek the same protection and dig their holes among the roots, giving channels for the water of the ensuing rain and fertilizing the spot with rejectamenta. Meantime the annual and semi-annual plants which maintain a precarious existence in the desert take root in the sheltered and fertilized soil beneath the growing cactus and mesquite, and in season it becomes a miniature garden of foliage and bloomage. Then certain ants come for the seeds, certain flies and wasps for the nectar, and certain birds to nest in the branches. In this way a community is developed in which each participant retains individuality, yet in which each contributes to the general welfare. So advantageous is the communal arrangement that few organisms of the drier portions of Papagueria pursue independent careers; the vast plains are dotted with communities or colonies from a few rods to some furlongs apart, while the intermediate stretches are practically lifeless; and the very soil is molded into a succession of hillocks with bare glades between, which persist even after the extermination of the colonies through climatal change or through human intervention. Thus do a large part of the plants and animals of the desert dwell together in harmony and mutual helpfulness; for their energies are directed not so much against one another as against the rigorous environmental conditions growing out of dearth of water.

This communality does not involve loss of individuality, which prevails throughout Papagueria—indeed the plants and animals are characterized by an individuality greater than that displayed in regions in which perpetuity of the species depends less closely on the persistence of individuals. By reason of this individuality there is a certain enmity between the animal and vegetal colonists. The small birds devour the seeds of the cactus and the squirrels nibble the beans of the mesquite, yet not all of the seeds are eaten, else a succeeding generation of birds and squirrels would starve; the spiders suck the blood of the flies and the wasps paralyze the spiders to serve as food for their young, yet not all of the flies and spiders are slain, else their enemies would famish; the hawks and eagles rend the small birds and squirrels, yet not all of the peaceful creatures are rent, else the birds of prey would perish; deer and antelope and, since the coming of white men, burros and kine crop the grass and browse on the tender twigs, yet not all the grass and young shoots are consumed, else the herbivores would suffer and die. In some respects the enmity of the colonists is more bitter than that of antagonistic species in humid lands; yet it is adjusted and developed into a marvelous solidarity under which the sum of possible vitality is increased apparently to a maximum; singly or collectively the colonies support more plants than they would be able to support without the aid of their animal associates in the distribution of germs and in fertilization; they support more insects than could live with a sparser flora; they support more herbivores than could be kept on a flora not fertilized by insects; collectively the colonies support a carnivorous fauna which could not exist if either the herbivorous things or the plants on which they live were destroyed. If the vitality of the desert were limited to any one type the sum would be reduced nearly or quite to nothingness, for few of the plants and none of the animals are independent of their communal associates. The solidarity of life in the desert is far-reaching and rises above the antagonism of individuals and species, for its strength is directed against the hard inorganic environment.

Commensality.—Over the great alluvial aprons and in other tracts of firm but not too stony soil the fields of the farmer ant abound. Where the soil is particularly suitable the farms adjoin and cover most or all of the surface over scores of square miles.

Each farm includes a clean and well-kept threshing-floor and drying-ground 5 to 30 feet across, with the passageway to the subterranean habitation in the center, and an annulus 3 to 20 feet wide of luxuriant grass, on whose seeds the ants subsist. Across these annuli run great turnpikes often a foot wide, connecting farm with farm, sometimes for furlongs. In such a farming district there is practically no vegetation except the cultivated grass; not only are other grasses and weeds kept down, but even the relatively mighty cactus, greasewood, and mesquite are apparently exterminated—certainly the prevailing plants of the region are absent from the most extensive and best cultivated farming districts. Thus the tiny formic farmers have developed an art of agriculture, have made conquest of the land for their needs, and have artificialized a plant apparently as completely as man has artificialized corn and rice; and in the process they have increased and multiplied to such an extent that they would die of famine in millions if their crop should fail, while it seems almost certain that their crop-plant would quickly die out if the cultivation and perhaps fertilization by the animals were withdrawn. Thus the rigorous environment of the desert has developed one of the most remarkable intelligences of the world, and has rendered two widely different organisms interdependent.

To the traveler the saguaro is, partly by reason of its loftiness, the most prominent element in the flora. Now the young stem of this cactus shoots with considerable rapidity as a rather slender column, at first without flower or fruit. After a period said to range from 5 to 10 years, and after a height varying from about 5 to 15 or more feet has been attained, the plant begins to bear and the rate of upward growth diminishes. Thereafter it slowly thickens and still more slowly increases in height; and in time branches start out at right angles to the trunk and soon turn upward to form a giant candelabrum. Now it is noteworthy that the height at which the saguaro begins to flower and fruit varies from district to district with the height of the local flora; in a district of greasewood and scrubby chaparral the flowering may begin at a height of only 5 to 8 feet, while in a district of vigorous mesquite the flowering may not begin until the stem is 10 feet higher. It is noteworthy also that in the typical districts the branches, if not more than 3 to 5 in number, usually spring from just below the height at which flowering began (the supernu-

merary branches spring either sporadically or above the ordinary level of the tops of the first crop), and that the branches always grow more slowly than the youthful trunk, perhaps no more rapidly than the well-grown trunk from which they spring. Thus the saguaro would appear to be in some way correlated with the surrounding vegetation, and while the correlation might be ascribed to soil differences it seems probable that the connection is more complex. On examining a large number of examples in many districts the impression is produced that the mindless aim of the saguaro, through the survival of the fittest, is first to rise above its neighbors rapidly as possible before expending energy in reproduction; that it then rests from the activity of stem-growth and divides its energy between gradual expansion and strengthening of the trunk on the one hand and reproduction on the other, yet continues slowly pushing upward until it dominates the landscape; and that when the main stem becomes extravagantly high the branches consume most of the energy of growth. A reason for this erratic behavior is found when it is observed that the flowers are fertilized by insects and that the seeds are distributed by birds; for it is manifest that the finding of the plants by flying things is facilitated by their great stature. Moreover the flowers are brilliantly white in color and attractive in perfume, while the fruit is gorgeously red and sweetly sapid. Still further it is manifest that the typical placing of branches is the most economical possible at once for the pumping of water from below and for bringing the flowers and fruits at the extremities within easy sight of the coöperating insects and birds. So it would appear that the saguaro is a monstrosity in fact as well as in appearance—a product of miscegenation between plant and animal, probably depending for its form and life-history, if not for its very existence, on its commensals. Whether the small black insects that suck the flowers and distribute pollen are wholly dependent on the saguaro for existence, like the yucca moth on the yucca (as shown by the lamented Riley), is questionable; and it is hardly probable that the birds that consume the saguaro fruit are so dependent on it as to have undergone actual differentiation of characters fitting them to the commensality.

The lesson of coöperation among subhuman organisms in Papagueria is the solidarity of life to the extent that the vital

energies of plants and animals are directed primarily against the inorganic environment, rather than against kindred and alien organisms, while one of the results of this solidarity is the development of strong individuality. By reason of this coöperation the desert was in part reclaimed and a series of superorganic organizations—unconscious and undesigned but none the less beneficial—was developed before the advent of man. In general, social and other institutions are a product of human intelligence alone; and it is of interest to the anthropologist to learn of the growth of organizations among lower organisms, and of special interest to study the effect on mankind of an environment so peculiar as to produce subhuman communality.

CHARACTERISTICS OF HUMAN LIFE

The Papago Indians are *the* desert people of North America. They dwell among the cacti, paloverdes, mesquites, and barren plains of a region in which human enemies cannot survive. They are semi-nomadic in habit; they migrate northward in spring, southward in autumn, with tolerable regularity, and remove their rancherias with the starting and failing of springs and with other changes in water supply. In the wanderings of generations they have acquainted themselves with meteorologic conditions and with every constant and inconstant source of water; thereby they have acquired an advantage over the invader, who is soon fain to retire or famish.

One of the first characteristics of the Papago to strike the observer is his capacity for abstinence: The Papago vaquero will ride one, two, or even three days without drinking, under a sun so fierce and in an air so dry that the tenderfoot dies of thirst in a few hours; and a family of a dozen often confine themselves for weeks to the contents of a single olla daily for drinking, cooking, and all other purposes. So, too, they live on reduced rations of solid food for considerable periods without inconvenience; indeed their habitual diet is moderate, even allowing for the condensed and nutritious character of some of their foods. When the interpreter was asked how the people of a rancheria were able to subsist for a winter on a certain limited supply of food, he replied, "They eat only twice a day, and if there is not enough they eat only once." The abstinence from solid food is in a measure apparent only, for the Indians are disposed to glut-

tonize in idleness when opportunity arises, when their capacity for consuming is no less striking than their power of abstaining. This characteristic of the tribe is possessed by other primitive peoples, perhaps in nearly equal degree; yet it is noteworthy as displayed among these Indians.

Another characteristic of the Papago is strength and fleetness: A withered crone (shown in the photographs of the expedition), weighing apparently not more than 80 or 90 pounds, arose from the ground with a kiho containing a stone mortar 196 pounds in weight, carried this burden more than half a mile over a sandy road, and then let it down from her back, and this without perceptible exhaustion or attracting particular attention among her neighbors. Many equally noteworthy feats of strength and endurance might be enumerated. Fleetness is displayed in the tribal game of kashâneku, or football, in which it is not unusual for contestants to run, kicking the ball before them, 30 or 40 miles in an afternoon. It should be observed that fleetness has apparently declined among the Papago since the introduction of the horse; yet they and other desert tribes have always been noted as runners: Bartlett found the Opata couriers to run 40 or 50 leagues (105 to 131 miles) in 24 hours, and Lumholz mentions that a Tarahumari Indian has been known to carry a letter nearly 800 miles in 5 days (these tribes belong to the same family as the Papago), while the Seri, who have never acquired the horse, are noted as *the* runners, par excellence, of this region of runners. Thus, although perhaps not especially distinguished, the Papago Indians are noted for strength, celerity, and endurance.

A third characteristic is apparent longevity: In every rancheria wrinkled and gray grandames and grandsires are found, generally in considerable numbers, and usually engaged in arduous labors; it is the aged woman who bears the heaviest burden, and her consort who performs the hardest field task, for the family. It is impossible to obtain exact figures concerning the age of the old people, but the proportion of the active aged is manifestly much larger than among civilized peoples. In this respect, too, the Papago is more or less like neighboring tribes, all of whom claim patriarchs and matriarchs who have far outlived the normal span of life.

Combining these and other characteristics of the desert tribe, it appears that they are in harmony with the characteristics of

the animals and plants; yet they are not so well developed as to clearly distinguish the Papago from other tribes, especially from those of other portions of the arid regions. When the physiologic or biotic characteristics of plants, animals, and men are compared it appears that the plants are most and mankind least modified in the direction of fitness to environment, the subhuman animal occupying an intermediate position.

Turning to the institutional or social aspect of the tribe, certain fairly distinctive characteristics are found, yet they are measurably masked by reason of the transition from the primitive state to the accultural condition initiated with the introduction of European crop-plants and stock. Fortunately there is a sufficient vestige of primitive culture to indicate many of the primitive customs. The Papago combined the chase for animal quarry with the search for vegetal foods; he gathered the fruits of various cacti and mesquite beans in season; he collected indurated pericarps and berries for beads; in his southward migrations he obtained seeds of corn and pumpkin as well as native beans—indeed it is probable that the primary purpose of the migration was the collection of seeds,—and on his return in the rainy season these were planted about the water holes and arroyo deltas, and in time the crop was gathered. There are indications that a tribal organization grew out of these customs; but this question need not now be pursued. It suffices to note that, as a consumer of seeds and fruits and as a distributer of seeds, the Papago entered into the vital solidarity of the desert and contributed toward the perpetuation of species that were good in his sight. In this way he made partial conquest of the soil and the productions thereof for his own behoof, and still further increased the sum of desert life; yet his conquest of the land at the time of the coming of the Spaniard was far from complete, apparently less complete than the conquest made by the farmer ant; and the historical Papago has never controlled the scant waters of his domain, but sought them where they chanced to occur in the hazard of storm and sun, just as he chased game and hunted wild fruits.

For three and a half centuries the Papago has been in contact with an alien culture, and there is evidence that during a preceding century or more he suffered through the repeated invasion

of his borders by his hereditary enemy, the Apache; thus the indigenous Papago culture can hardly be considered as independently autochthonous or indigenous—the process of culture development was undoubtedly effected by external influence. Fortunately the prehistoric remains of Papagueria throw light on an antecedent culture which appears to have been essentially indigenous; and there is reason for opining that the prehistoric peoples were the direct ancestors of the Papago and certain other southwestern tribes.

The prehistoric remains comprise greatly reduced ruins of villages and irrigation works, as well as "las trincheras" (or intrenched mountains), with included or associated pottery of fine texture and finish, and highly polished stone implements; these relics being abundant and distributed over a considerable part of Papagueria. Now, on comparing the ruins with modern artificial works (including those of the sedentary Mexicans who have pushed far into the arid district) certain important differences are found: In the first place the ancient villages were much larger than the modern rancherias of the Papago; in the second place the ruins are much more numerous than the Papago rancherias and Mexican settlements combined; again the ancient irrigation works (of which the Papago have none) are much more extensive than the modern acequias, dams, and reservoirs of the Mexicans; and finally the trincheras are unique. The great extent of the prehistoric irrigation works is especially impressive; the ancient acequia in Arivaca valley was raised above the flood-plain and 150 feet in width, the confining banks being occupied by nearly continuous rows of habitations, while the modern acequia, put in through American enterprise, is a simple ditch 8 to 10 feet wide; and a single one of the many prehistoric villages in the valley comprised 130 habitations, or fully twice as many as those of the modern American, Mexican, and Indian inhabitants. It may be noted also that a village in this valley and one or two others elsewhere have remains of what appear to be corrals containing tanques for water, indicating the domestication of a rather small animal (perhaps the vicuña). Viewed collectively, the prehistoric remains indicate an ancient population much more extensive than that of the present; for the great number of the villages may not be ascribed to successive occupation, since the irrigation ditches are so large and carried so far up the valley sides as to be

adequate for the supply of a large contemporaneous population and at the same time to be inconceivably extravagant if only a small population were to be supplied at a given time. It is of course possible that the prehistoric precipitation was greater than that of the historical period, but there is no special warrant for this supposition, which is moreover inherently improbable and also unnecessary. It may be observed summarily that the archeologic and ethnologic data in the region indicate a numerous and peaceful agricultural population at a period probably between two and five centuries before the Spanish invasion, and suggest (1) that this population began to suffer from forays by a predatory enemy dwelling in the high Sierra, (2) that the system of forays gradually grew into warfare for vengeance and reprisal, (3) that the peaceful folk found a temporary refuge in the trincheras, and (4) that the irrigation works were finally destroyed, whereby the valley tribe was all but annihilated and driven partly into the remoter desert fastnesses, partly into the more northerly valleys tributary to the Colorado—the desert remnant being the immediate ancestors of the Papago. It is not necessary to dwell on the details of this succession or even to affirm its verity beyond the trustworthiness of a good working hypothesis; the essential point, which seems to be indisputable, is that the district supported a numerous agricultural or largely agricultural population, who were able to maintain themselves, despite the prevailing aridity, by means of an elaborate system of irrigation. This population and culture seem to have been essentially indigenous, and, up to the time of decadence, not greatly influenced by external conditions. Accordingly, during the prehistoric period represented by the ruins, the indigenes of Papagueria made conquest, not only of the soil as do the modern Papago, but of the waters; and thereby their culture rose to a higher plane, yet a plane which may justly be regarded as normal to the desert.

The lesson of human life in the desert is found in the coöperation between men, animals, and plants in such wise that the sum of vitality is multiplied and at the same time subordinated to intelligence: Man consumes fruits and seeds, yet distributes the germs of plants useful to him; as he advances in culture he conserves the germs unto the season of germination; he either neglects or directly destroys useless and noxious plants; and in

all these ways he improves the flora. Man subsists in part on game, yet, under the economy of solidarity, he does not exterminate the game animals and thereby cut off a supply at its source, but rather coöperates with them in a communality analogous to that between the animals and plants; he aids, albeit unconsciously, the herbivores in escaping the carnivores, and for this service they pay tithes in flesh; he even enters into coöperation with carnivores, such as the coyote, which he spares to become his scavengers, and they reciprocate by forming a semiconscious cordon of protectors about the camp or village; and in these and other ways a partial cultivation of plants and domestication of animals is brought about collectively, and man enters into and dominates the solidarity of desert life. Then if peace persists he begins to transport and preserve water, and this is the germ of irrigation by which the wilderness is made to blossom and by which both plants and animals are multiplied and artificialized.

INTERRELATIONS OF LIFE

When the plants, animals, and men of the desert are compared with respect to physiologic or ontogenic characters, it is found that the stationary plants have suffered greatest modification, the environment-driven animals less, and the environment-molding humans least of all; but when they are compared with respect to collective or demotic modification, it becomes manifest that the moveless plants are least, the moving animals more, and prevising men most profoundly modified.

When the life of the desert is compared with the vital phenomena of humid regions, it is found that under the pressure against an adverse inorganic environment, the beginning of the control of environment springs lower on the stem of phylogenic development—that the desert species, genera, and orders enter into a mutually beneficial coöperation while yet the rain-fed organisms are frittering energy in internecine strife. Thus it would appear that among plants and animals, as among men, hard necessity is the mother of progress. It would also appear that among plants and animals, as among men, strength lies in union; and progress in combination leads to solidarity.

The great lesson of plants, animals, and men in the desert is found in the modification of organisms and the development of

organizations: Under the hard environment, organisms cease to strive against one another and each strives against inorganic nature; under the common pressure they are forced into union, and thus coöperation is initiated. Now there are three stages in coöperation; the first stage is that in which the organisms merely stand together for mutual protection, but retain undiminished individuality—this is communality; the second stage is that in which individualities blend through miscegenation between unlike organisms, as between the yucca and yucca moth—this is commensality; the third stage is that of voluntary inclusion and exclusion of organisms for the common welfare of the solidarity or for the especial weal of the dominant organism, whether ant or man—this is the stage unwittingly, yet not unhappily, called agriculture.

The lesson of life in Papagueria may easily, and within limits safely, be extended to other regions; for the phenomena and relations are more or less closely paralleled elsewhere. It may appear paradoxical to affirm that it is in arid districts, where agriculture is most arduous, that agriculture began; yet the affirmation is not gainsaid but rather supported by history, and is established beyond reasonable doubt by the evidence of the desert organisms and organizations.

So, whatever its last estate, in its beginning agriculture is the art of the desert.